



**QUEEN'S  
UNIVERSITY  
BELFAST**

## Virtual Reality as a tool to Assist Learning in Aerospace Assembly

Gibson, Z., McGeown, M., Butterfield, J., Marzano, A., & Murphy, B. (2016). *Virtual Reality as a tool to Assist Learning in Aerospace Assembly*. Paper presented at International Manufacturing Conference, Limerick, Ireland.

**Document Version:**  
Other version

**Queen's University Belfast - Research Portal:**  
[Link to publication record in Queen's University Belfast Research Portal](#)

**Publisher rights**  
Copyright 2016 IMC33

**General rights**  
Copyright for the publications made accessible via the Queen's University Belfast Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

**Take down policy**  
The Research Portal is Queen's institutional repository that provides access to Queen's research output. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact [openaccess@qub.ac.uk](mailto:openaccess@qub.ac.uk).

# **VIRTUAL REALITY AS A TOOL TO ASSIST LEARNING IN AEROSPACE ASSEMBLY**

Z. Gibson<sup>1</sup>, R. McConnell<sup>1</sup>, M. McGeown<sup>1</sup>, J. Butterfield<sup>1</sup>, A. Marzano<sup>1</sup>,  
B. Murphy<sup>2</sup> & Karen Rafferty<sup>2</sup>

1. School of Mechanical and Aerospace Engineering, QUB
2. School of Electronics, Electrical Engineering and Computer Science, QUB

## **ABSTRACT**

This study examines whether virtual reality (VR) is more superior to paper-based instructions in increasing the speed at which individuals learn a new assembly task. Specifically, the work seeks to quantify any learning benefits when individuals are given the opportunity to review instructions in advance of the task. It compares the performance of two groups using virtual and hardcopy media types to pre-learn an aircraft panel assembly process. A build experiment utilising multiple builds of the panel showed that a group of people, who pre-learned the assembly sequence using a VR environment, completed their builds faster (average build time 29.5% less) with fewer references to instructional materials (average number of references 38% less) and with fewer errors than the group using hardcopy instructions. These outcomes were more pronounced during the first build, with differences in build time and number of references in subsequent builds showing limited statistical differences.

**KEYWORDS:** Virtual reality, learning, assembly

## **1. INTRODUCTION**

The current economic climate places increasing pressure on engineering companies to take action to retain or improve competitive advantage. As a result, many companies have attempted to reduce product development cycles to meet the increasing demands of its customers for reduced delivery lead times [1]. Extra time gained from more efficient production methods could contribute to these reductions as the faster an employee can learn to assemble a given product, the more efficiently the company can produce it. The proliferation of digital tools that have become available to engineers across all disciplines contributing to the manufacturing enterprise (e.g. advanced computer aided design, manufacturing simulation, virtual reality) now mean that there are opportunities to exploit these technologies in knowledge capture and exploitation. This can then improve the product development process delivering the improvements required for manufacturers to reduce delivery lead times and improve quality.

To examine the potential and relative merits of the learning tools and media types available in contemporary engineering simulation platforms, the theory of the learning curve can be applied. Wright [2] first applied a learning curve to the assembly of an aircraft. His work determined that the labour costs and the time taken to build a product can be reduced with each successive build. Butterfield et al [3] demonstrated that a learning curve could be used to

determine the effectiveness of instructional media. They examined the build times for an aerospace assembly and found that a group that used animated, digital instructions performed better and with lower total build times than a group supplied with paper instructions. In 2005, Mayer et. al. [4] carried out a comparative study looking at the effectiveness of annotated illustrations compared to narrated animations as learning tools. The study showed that a group using paper instructions outscored a computer based group on a series of retention and transfer tests. Virtual Reality (VR) has already shown success in aiding the learning process in a number of instances. For example, Carlson et al [5] studied the differences in learning between VR and physical training on a manual build of a six-piece burr puzzle. The VR group was outperformed by the group who learned from physical training on initial tests, but appropriate use of colour cues in VR can make it as effective as physical training performance. Although the above work enabled the direct comparison of performance based on various instructional types, they did not explore the potential benefits of using simulated environments to pre-learn a task. Pre-learning has the potential to allow operators to descend the learning curve before their employer invests in physical assets.

The aim of this paper is to quantify the pre-learning benefits of using a Virtual Reality based assembly environment relative to hardcopy, paper based instructions in an industrial context. The work recreates a real aircraft panel assembly cell (see Figure 1) in the virtual environment and provides means by which the user can both visualise and interact with the panel and its assembly fixture. This in turn allows a direct comparison to be made between assembly times for equivalent build procedures in both a real and a virtual setting.

## **2. METHOD**

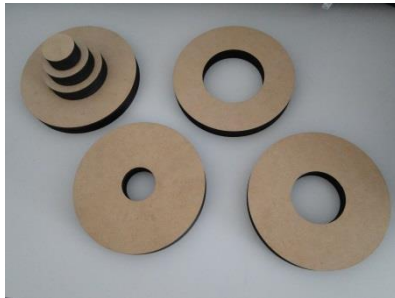
### **2.1 Equipment**

A combination of physical and virtual control [6] was utilised in this experiment to allow the user freedom of movement that closely resembles the real world. The panel geometry was created using CATIA CAD software and the user's actions were translated into the virtual world using Vizard virtual reality software. Vizard code was also used to translate the panel geometry between the CAD and VR environments. A head mounted display (HMD) was used to visualise the build. This included a motion sensor that allowed the virtual viewpoint to change based on the head movements of the user. A Nintendo Wii controller was used to move around the environment and interact with the panel components. Again a sensor was used to transfer actual hand movements to a virtual hand. Actions associated with finger movements were controlled by coding buttons on the controller to perform pre-defined tasks such as grab and release. Detailed paper based instructions including isometric images were generated in Microsoft Powerpoint. These were issued to all participants completing the physical build.

### **2.2 Procedure**

Ten undergraduate student participants were recruited from Queen's University Belfast for the experiment. None of the participants were familiar with the panel and had no prior knowledge of aircraft panel assembly methods. The students were divided into two groups of five with one group completing an initial virtual panel build and one group learning from written instructions. Both groups were provided with hard copy images to guide them through the build. This included an isometric view of the panel showing part locations as well as labelled part numbers to aid part identification. The VR group used this to guide the virtual builds. Parts were arranged in the required order on a virtual table. Their relative position indicated the sequence in which they were used. In the case of the hard copy instructional group, the images were supplemented with a verbal description of the build.

For the group completing the virtual builds, all participants completed a 'pre-learning' stage. They were offered a practice session using the VR technology before completing the panel build. This involved a simple task requiring the assembly of three wooden discs onto a tiered peg (see Figure 2).



**Figure 1:** Aircraft panel & Fixture. **Figure 2:** Tiered Peg & Discs (Unassembled)

This enabled them to gain familiarity with the VR equipment which ensured that any learning associated with the later panel build task was associated with the panel itself and not the VR equipment used for the experiment. They then were given an hour to complete the virtual panel build using a component map of the assembled panel which included part numbers to guide the build order.

The second group was given detailed written instructions which included static, isometric images. Each participant was given an hour to review the assembly process in advance of the physical build.

All participants completed five consecutive physical builds over an eight day period (a weekend break was included due to the number of builds required). The total time to complete each build, the number of references to the instructions and the number of errors that participants made were recorded.

### **3. RESULTS**

**3.1 Build Times:** Decreasing build times were observed for all participants for every consecutive build. Figure 3 shows the learning curves combining average build times for the two groups tested. This shows that on average, the VR

group’s learning curve is lower than the paper group initially but the results for builds 2 to 5 are close enough to have limited statistical relevance. The VR group completed build one on average 29.5% faster than the paper group.

**3.2 References to Instructions:** Trends for the number of references (see Figure 4) were similar to those for the build times. The number of references to instructional media decreased with the number of builds and there was no statistical difference between the two groups from builds 2 to 5. The greatest difference occurred during build one where the VR group made 38% fewer references than the hardcopy instructional group.

**3.3 Errors:** Like build times, error counts decreased with build number. It was difficult to draw relevance from error data between groups as some of these appeared random, making the identification of trends across the five builds difficult. For build one, the VR group made 41% fewer errors on average.

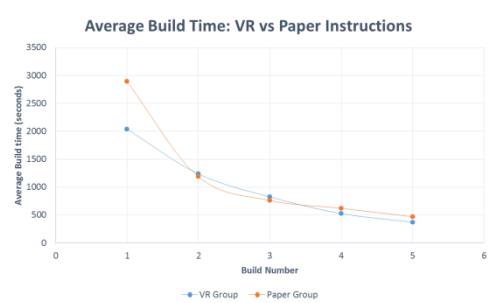


Figure 3: Build Times

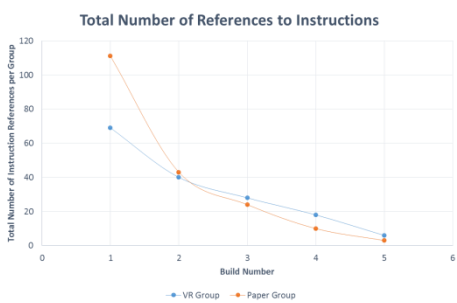


Figure 4: References to Instructions

4. DISCUSSION

The outcomes from this experiment confirm the basic principle of the learning curve where the time taken to complete each assembly reduces with repeated builds for both groups. The experimental data generated for build one carries the most significance. In the context of build times, VR is a superior tool for pre-learning with average build times 29% faster than the hardcopy instructional group (see Figure 3). This can be attributed to Cognitive Load Theory (CLT) [7]. Whereas the hard copy instruction group were required to read text and process images in order to understand the build sequence for the panel, the VR group (even though they were guided by a static image for instructional purposes) had the benefit of completing a virtual build prior to completing the test. This reduced cognitive load as the opportunity to interact with and visualise 3D virtual components enabled a better understanding of part shapes and locations within the assembly. The lower build times could also be attributed to kinaesthetic learning (learning by doing) [8] prior to the timed builds. Beneficially, this improvement was achieved without physical assets. Thereby, VR has the potential to deliver huge advantages in an industrial setting as fitters could descend the learning curve without the need or cost associated with real fixtures or components. The added benefit of this approach is that any

build issues could be identified and corrected before production begins, saving time and therefore cost in corrective work on fixtures and tools. The VR group also displayed a smaller standard deviation (648.97 compared to 931.07). This indicates that the VR group performed more uniformly than the paper group after they integrated the knowledge gained from the pre-learning stage.

The results regarding references to instructions produced a similar trend to that seen in build times. Build one produced the largest difference with the VR group requiring 38% fewer references. This indicates that the VR group may have retained more information than the hard copy instruction group through a more effective pre-learning experience. The number of references made by both groups was similar for builds two to five. This shows that the benefit of pre-learning with VR was more pronounced at an early stage before both groups learned at a similar rate by completing the final, timed builds.

Product quality is of high importance in the aerospace industry and minimising errors is important to maintain reputation and product safety. This experiment showed that error levels were generally lower for the group using VR for pre-learning. As errors could be related to the practical ability or attention span of the participant, it is complicated to tie errors directly to the instructional type, and therefore it is difficult to draw any firm conclusions from this outcome.

Although this work demonstrated potential benefits for the use of VR in pre-learning assembly tasks, the results in this instance were based on the actions of the test participants having made decisions after reviewing the instructions. These have been explained in terms of the observations of others [7] using CLT. VR is a powerful tool and in order to gain further understanding of how humans interact or can benefit from this technology, it would be useful to gain further insights into the way people process information when immersed in a virtual environment. This could be based on how their mind reacts to the instructional type or environment before they make a decision and take action. Teo et. al. [9] used physiological devices to assess workload based on the remote operation of unmanned systems. They used electroencephalography (EEG), electrocardiography (ECG), a transcranial Doppler (TCD), functional Near-Infrared (fNIR), and eye tracking technologies. The outputs from the physiological devices informed developers about the sensitivity of various workload measures in assessing levels of mental demands imposed by working with unmanned systems. The decision as to what device to use varies depending on the particular application, the main conclusion in the context of our work is that physiological data can be used to assess the human capacity to manage workload. With respect to EEG technology Bashivan et. al. [10] utilised it to predict and track cognitive states. They examined responses to instructional and recreational videos and the results demonstrated the significant potential of EEG devices to differentiate cognitive states between situations with large contextual but subtle apparent differences. This shows that EEG could be an important technology for future use when looking at improving the learning process in manufacturing settings.

Furthermore, Strickland et. al. [11] used EEG to understand the mental processing differences between artificial and real scenes. They concluded that differences do exist between real and virtual image processing with variations affected more by subject and task than by which area of the brain is processing the image. Based on the literature it is clear that there is potential to further optimise virtual environments for learning purposes through the use of physiological devices to gain a better understanding of how learning materials and environments affect participants' mental responses prior to making a decision to act.

## 5. CONCLUSIONS

1. Virtual reality offers learning benefits when used for pre-learning in an assembly context
2. This benefit is more pronounced in the early learning stages before participants have the benefit of completing multiple builds when they learn from doing.
3. The use of physiological devices to record mental reactions as people review and implement assembly based instructions, has the potential to provide better understanding of how work instructions can be best tailored to improve human performance.

## 6. REFERENCES

- [1] Infor,. Manufacturing and the Demanding Customer. *Infor.com* (2014). Retrieved 14 June 2016, from: <http://www.infor.com>
- [2] Wright, P. T. Factors Affecting the Cost of Airplanes, *Curtiss-Wright Corporation*: (1936) 122
- [3] J., Butterfield, R., Curran, G., Watson, C., Craig, S., Raghunathan, R., Collins, & C., Gibson Use of digital manufacturing to improve operator learning in aerospace assembly. *Paper Number: AIAA, 7865(7)* (2007).
- [4] R. E., Mayer, M., Hegarty, S., Mayer, & J., Campbell When static media promote active learning: annotated illustrations versus narrated animations in multimedia instruction. *J. Exp. Psychol.-Appl.*, Vol.11 (4), (2005), 256.
- [5] P., Carlson, A., Peters, S. B., Gilbert, J. M., Vance, & A., Luse Virtual Training: Learning Transfer of Assembly Tasks. *IEEE Trans. Vis. Comput. Graphics*, Vol.21 (6), (2015) 770-782.
- [6] M. R. Mine, "Virtual Environment Interaction Techniques." Technical Report TR95-018, University of North Carolina at Chapel Hill. (1995) 2.
- [7] F., Paas, A., Renkl, & J., Sweller. Cognitive load theory and instructional design: Recent developments. *Educ. Psychol.* Vol.38 (2003)
- [8] C. J., Olsson, B., Jonsson, & L., Nyberg. Learning by doing and learning by thinking: an fMRI study of combining motor and mental training. *Front Hum Neurosci*, Vol. 2(5) (2008).

- [9] G. Teo, L. Reinerman-Jones, G. Matthews, J. Szalmab. Comparison of measures used to assess the workload of monitoring an unmanned system in a simulation mission. *Procedia Manuf.* 3, (2015) 1006-1013.
- [10] P. Bashivan, I., Rish, & S., Heisig. Mental State Recognition via Wearable EEG. *MLINI 2015 - 5th NIPS Workshop*. December 11-12, Montreal, Quebec, Canada, (2015).
- [11] D. Strickland, D. Chartier. EEG Measurements in a Virtual Reality Headset. *Presence*, Vol.6 (5) (1997) pp.581-589